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This report describes the items purchased under the second project, summarizes their use to date, and details how these equipment have increased the research capability of MSU toward assisting DoD with development of cleanup technology.

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10 October, 2001

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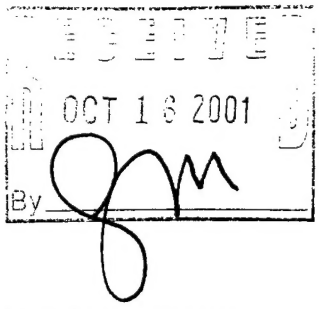

RE: Submittal of Final Technical Report for Contract No. DAAD19-00-1-0056 (DURIP Project)

Dear Army Research Office,

Enclosed is our final report concerning the DURIP project that Mississippi State University (MSU) just completed (reference contract number above). The report details all requested information, plus additional information considered of interest to ARO. Please note that the purchase orders for MSU to the equipment vendors are included as Appendix A of the report enclosed.

I would like to express our deepest gratitude to ARO for playing a major part in enhancing the research capability of MSU for assisting DoD with its environmental research initiatives. Your support has already paid off in terms of new DoD interactions and contracts. Also, numerous graduate students have benefitted from your support via the usage of the equipment during their graduate studies. Many of these students are from under-represented minority groups. Thanks.

Very Sincerely Yours,

Mark E. Zappi, Ph.D., P.E.
Professor and Director of the
MSU Environmental Technology Research and Applications (E-TECH) Laboratory

FINAL REPORT ON RESULTS OF DURIP PROJECT

Analytical System for Identification of By-Products Produced from the Incomplete Degradation of Relevant Department of Army Contaminants During Treatment Activities-II

Targeted Sponsoring Agency: US Army Research Office (ARO)

Principal Investigator: Dr. Mark E. Zappi, P.E.
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Contract Number: DAAD190010056 00020153

Amount: ARO - $100K and MSU Match - $18K (Actual was >$20,000)

Project Duration: March 31, 2000 - March 31, 2001

INTRODUCTION

The Department of Defense (DoD) has numerous facilities that have become contaminated from past military activities ranging from weapons production to machinery maintenance to practice range operations The result of these activities are sites within DoD facilities that contain literally millions of cubic yards of contaminated soils and billions of gallons of contaminated groundwaters. Both inorganic and organic contamination have been detected. Additionally, the DoD produces millions of gallons of contaminated waters daily from on-going military activities requiring treatment. A recent user poll, based on a survey of base and Command personnel conducted by DoD, determined that the primary concern with regard to DoD contamination is the lack of economically and technically feasible treatment techniques for media contaminated with organic compounds. A recent DoD report to the US Congress concerning the extent of contamination at military bases indicates the following organic contaminants are problematic to the DoD:

1. Explosives - Extensive contamination of both soil and groundwater from manufacturing, loading, ignition, and disposal activities. Examples include TNT,

RDX, HMX, Tetryl, TNB, and reduced nitroaromatics (ADNTs, DANTs, and TAT). Additionally, there is still not a fully developed economically and technically feasible technique for manufacturing wastewaters (red and pink waters).

2. Petroleum Products - The most prevalent contamination type at DoD facilities that is present due to activities associated with vehicle operations, facility heating, tool machining, and wash rack facility operations. Examples include simple aromatics (i.e. benzene and ethylbenzene) and polycyclic aromatic hydrocarbons.

3. Solvents - The second most prevalent form of contamination that is present at DoD facilities due to machining operations, weapons production, and vehicle maintenance activities. Examples include trichloroethylene, perchloroethylene, acetone, and toluene.

4. Phenolics - Significant contamination from weapons production and wood preservation activities. Examples include nitrophenols and chlorophenols.

5. Chemical Weapons - A large number of chemical weapons are currently stockpiled by the DoD in aging storage vessels. At some installations, past production activities have resulted in environmental contamination of both product and manufacturing waste products. Examples include nerve agents and by-products such as diisopropylmethylphosphonate (DIMP).

6. Polychlorinated Biphenyls (PCBs) - The extent of the PCB problem to the DoD is actually twofold. In terms of base closure and active base cleanup, many installations have several small sites of PCB soil contamination due to leaks and/or improper disposal of hydraulic fluid, carrier oils, and electronic equipment insulator fluids. In terms of the dredging mission of the US Corps of Engineers and US Naval facility maintenance, PCB contamination represents the most challenging and prevalent sediment contamination problem. Recently, the USEPA reported that only incineration was considered a fully developed treatment technology for PCB contaminated media.

7. Other Contaminants - Many other contaminants are considered of DoD interest which include dioxins (Agent Orange handling and disposal), pesticides (leased facilities [RMA] and base maintenance), anti-fire fighting chemicals (typically found around fire fighting practice areas), nitroglycerin (from production, detonation, and disposal of weapons), and hydrazines/nitroso by-products (rocket fuel blending).

Clearly, the environmental remediation challenge facing DoD is immense. When comparing the total estimated cost of installation restoration, the cost of the total research and developmental effort in environmental cleanup can easily be justified with savings from the remediation just of few

sites that utilize these newly developed technologies. Additionally, current cleanup efforts at many DA Sites require such extensive O&M budgets that funds under the DERP Program are being utilized at an alarming rate toward cleanup maintenance and not the initiation of new cleanup efforts. Past and proposed BRAC initiatives further exasperate a growing fiscal and environmental problem facing DoD. Unfortunately, the DA appears to have over one half of the estimated 12,000 DoD sites that have been identified as requiring some form of remediation.

PROBLEM

The fate of an organic compound during treatment in terms of chemical degradation pathway is a major consideration during the complete development of a remediation process. Typically, a compound is transformed or degraded following a stepwise reaction-based pathway starting with the parent compound passing through various by-products (or daughter products), eventually leading the formation of reaction end-products. When the end-products of a treatment reaction are all of inorganic composition, then the compound is said to have been mineralized. Degradation does not mean that the parent compound has been mineralized, but mineralization infers degradation.

There have been many significant accomplishments made by research sponsored or performed by DA research groups in the area of treatment process development. However, in some cases, the DA has overlooked full technology development in terms of identifying potential by-products of incomplete degradation. Composting is an example of this type of development. After years of development, the DA announced that composting was fully developed, yet to this day, the DA continues to research and defend the actual status of this technology because full definition of explosive degradation during composting was not made. Many within the scientific community continue to question the mechanisms and environmental safety of applying composting due to the lack of proven mineralization and supporting mass balance defining TNT fate. The DoD needs to champion the concept that removal of a parent contaminant does not constitute technology development. It is realized and appreciate that determining parent compound removal does define technology promise. However, development efforts should also focus on the extent and rate of removal of by-product formation, removal, and mineralization.

In order to properly develop new and innovative treatment processes, Mississippi State University (MSU) submitted two DURIP proposals to ARO for the purchase of a system of key analytical equipment components for identification and tracking of organic pollutants undergoing treatment. This "systems" approach was actually proposed as a two separate DURIP proposals (FY1999 and FY2000). Both proposals were funded. The first award allowed MSU to purchase a GC/MS and a sample oxidizer (for combustion of solid matrices containing radiolabeled isotopes).

The second DURIP funding was awarded to MSU a year later and was used to purchase the equipment described in this report. This report describes the items purchased under the second project, summarizes their use to date, and details how these equipment have increased the research capability of MSU toward assisting DoD with development of cleanup technology.

DESCRIPTION OF PURCHASED EQUIPMENT

The system that was purchased using the subject DURIP funds provided to MSU was an ion chromatography (IC) system, total organic carbon (TOC) analyzer, and a gel permeation unit. Note that MSU provided a match of $20,000 for this effort. A brief description of the components of these system components as purchased by MSU is presented below. In addition to the items listed below, a small laboratory freezer ($385) and an extract controller ($7,100) were also purchased to support the total system purchased by ARO and MSU.

Appendix A contains copies of all of the MSU purchase orders for the equipment purchased under this contract. In total, over $120,000 of new equipment was purchased with the funds.

Ion Chromatography (IC) System - A Dionex 600 Series Ion Chromatography unit was purchased and installed within the new chemical engineering building (Dave C. Swalm Chemical Engineering Building) during the contract period. The unit is fully equipped with features including an autosampler, system of columns (inclusive of a guard column), software, and computer. The system 600 Series provides a high level of automation allowing for improved performance over traditional IC units because it limits the impact of operator error by using preset operational functions to perform a given programmed task. This is a particularly attractive feature to an university, such as MSU, which, by mission, has equipment operated by several graduate students and research faculty.

The total cost of the IC related purchases was $41,236.00 and were purchased directly from Dionex. Inclusive within this price was training at MSU on the operation of the unit, with the actual installation of the system performed during May, 2001. The tardiness of this installation occurred because the contractor (MSU Chemical Engineering Department - Zappi) was moving into a new building over the course of the previous six months. The laboratories within the new building were actually fully operational in March 2001.

The IC unit has been configured to focus on identification of anions derived from effluents obtained from oxidation units treating TNT within aqueous streams. Mineralization of the nitro-groups to nitrate and ammonia is being assessed using this system. Using the IC, along with the TOC analyzer and ultimately C^{14} labeled TNT, will allow for a very convincing argument to be

made concerning the extent of mineralization obtainable within the proposed treatment scheme being developed under ARO funding. This unit provides our group with a state-of-the-art system for analyses of both cations and anions, plus the addition analytical capability for simple sugars and carboxylic acids - which is currently on interest by our group, given the recent award of a DOE grant to study the conversion biomass to ethanol.

Total Organic Carbon Analyzer (TOC) - A Shimadzu Model 5000A unit was purchased and installed within the laboratory over the course of this contract. The unit has capability of analyzing both liquid and solid matrices for both organic and inorganic carbon (often referred to as a TIC/TOC system). The unit at MSU includes an autosampler and data processing system that was installed on a IBM format computer.

The total cost of the unit was $34,372 and was purchased directly from Shimadzu. Inclusive within this price was training for operation and maintenance of the unit. It was installed during the Spring 2001 within the new chemical engineering building at MSU.

The unit is one of the most utilized analytical instruments within the Environmental Technology Research and Applications (E-TECH) Laboratory at MSU (a research entity at MSU directed by Dr. Zappi). It has been used to support an ARO contract on the development of a reductive/oxidative water treatment system for TNT. The TOC data generated for this project has clearly shown that the hypothesized system was indeed capable of full mineralization of TNT within an aqueous media. The treatment system used to produce these results first involved treating a TNT spiked water sample with zero-valent zinc (for reduction of one or more of the nitro-groups into a reduced amino group [and other reduced products]), followed by oxidation of reduced products using peroxone (ozone and hydrogen peroxide). Both aqueous and metallic samples have been analyzed for TOC conversion into inorganic forms (defining mineralization). Numerous samples from an USEPA funded project have also been run on the unit for development of an ozonation-based water treatment process for wood preserving wastes within groundwater. These samples were used to track the fate of aromatic hydrocarbons during ozonation of a groundwater sample (at both the bench and pilot scale).

Gel Permeation System - The final purchase was a Waters Model Gel Permeation Unit. This system included a HPLC pump, autosampler, 2 channel VIS/UV detector, and two cleanup columns. The total cost of this system was $36,551. It was purchased directly from Waters and installed during Spring of 2001.

This unit was purchased as a method to "clean" extracts from soil samples for subsequent

analysis on a GC, HPLC, or GC/MS. In fact, in support of this system, an additional piece of equipment, a solvent management system, was purchased under these funds ($7,000) to enhance the capability of the Dionex auto-extractor (purchased previously by MSU to enhance the performance of the system) to better control extraction fluid content prior to feeding into the gel permeation unit. However, it was found during the initial operation of the unit, that extraction fluids used by MSU (such as acetone and acetonitrile) were degrading the polymers within the cleanup columns. In fact, no match could be made for the system, given the aggressiveness of the extraction fluids used by MSU. Therefore, Waters agreed to convert, free of charge, the unit into a HPLC system for dedicated use by MSU for analysis of soil and waters for explosives content. This alternative option provides MSU with a much-needed capability for analyzing explosives, given the high volume of research on-going in this area.

BENEFIT TO MSU CAPABILITY

The new equipment complements some equipment already in place within the E-TECH Laboratory of MSU by providing the capability to effectively define the fate of both parent compounds and associated degradation products during treatment. MSU had previously been funded by ARO under DURIP for the purchase of a GC/MS and a Sample Oxidizer using previous FY funds. This current contract allowed MSU to complete a system, which provides MSU with the capability to evaluate the degradation pathways of DoD contaminants undergoing treatment. This positions MSU to be a leader in the support of DoD's efforts to develop cost effective remediation options for its more than 12,000 sites worldwide.

MSU has not only been active in 6.1 technology development, but it is also actively involved in technology maturation and optimization in partnership with several DoD entities. Often, as newly discovered technologies are applied to various actual wastewaters, groundwaters, and/or soils composed of very differing chemical matrices, the performance of the technology in question can differ dramatically. This important developmental step is often over-looked or its importance understated. In most cases, rarely does the first prototype function at an optimum. Further development is needed to complete the developmental task. MSU has been very active in this area working with various DoD entities (further discussed later). Proper process optimization should be performed by those research groups having developmental experience at both the 6.1 and >6.2 levels. MSU has this rare capability that has and should continue to be an asset to various DoD entities. Currently, several innovative technologies are under development by ARO and other DoD entities

that can dramatically improve both economic and technical performance over even the most recent fully developed technologies. New research initiatives are underway that will continually improve DoD readiness for both improved treatment performance at reduced cleanup cost. In order for DoD to meet these challenges, institutional capability needs to be in place to support these efforts. As these innovative technologies are applied to many sites with very differing chemical matrices, the DoD will require laboratory resources where evaluation (treatability) and applied research (process enhancement) can be performed in support of technology application and maturation. The function of these laboratories will be to (1) ensure that appropriate degradative mechanisms are appropriately degrading the parent and known by-product compounds, (2) evaluate the impact of differing environmental matrices on process performance, and (3) provide testing to determine causes of potential system failures which will contribute to the overall knowledge of the applications potential of the technology (i.e. define process limitations). The E-TECH Laboratory of the Dave C. Swalm School of Chemical Engineering at MSU is rapidly gearing itself to not only be a technology development asset to the DoD, but be a key support entity to assist the DoD with technology performance evaluation and optimization. The purchased equipment has provided a tremendous gain to meeting these bold objectives.

UTILITY OF REQUESTED EQUIPMENT TOWARD DOD MISSION

Several projects are currently being performed within the MSU Department of Chemical Engineering's E-TECH Laboratory using funding from DoD and/or other federal funding entities. A brief listing of each project will be presented below, along with how the requested equipment will be or is used within each project.

Development of Integrated Abiotic-Biotic Processes for Remediation of TNT Contaminated Environmental Media - (Sponsoring Agency: ARO) - This project is part of the DEPSCOR program. The project was funded in FY99 (three year funding). The objective of this effort is to evaluate hyphenated technology approaches for the improved treatment of TNT contaminated media. The overall concept being that several reductive reactions can be used to reduce TNT into aminonitrotoluenes that are much more reactive to chemical oxidizers than TNT. Plus, aminonitrotoluenes do not form trinitrobenzene (a highly regulated by-product of incomplete TNT oxidation). Among several research objectives is the definition of reductive-oxidative pathways which is critical because of the potential formation of environmentally hazardous by-products, if the hypothesized mechanism is proven to be minor.

Peroxone and Ozone Oxidation of Chlorinated Phenols - (Sponsor Agencies: WES and USEPA via the Gulf Coast Hazardous Substance Research Center) - This project was initiated at MSU in FY95 under the Strategic Environmental Research and Development Program (SERDP) through a contract with the USAE Waterways Experiment Station (WES), it has since continued development of oxidation processes via a recent USEPA grant. However, collaboration continues with WES via a research agreement that is unfunded, but provides excellent technical exchange which has recently lead to the publication of two peer-reviewed publications.

The objective for this effort is twofold. The first objective is to determine the effectiveness of peroxone oxidation and ozonation for the removal of six dichlorophenol (DCP) isomers from aqueous media. The second objective is to incorporate ozone mass transfer models into existing oxidation kinetic models to eventually formulate design quality models for future 6.3/6.4 efforts. Stopped flow spectrophotometry was used to evaluate ozone-DCP reaction kinetics. GC/MS, GC, and high performance liquid chromatography (HPLC) have been successfully used for tracking DCP fate during treatment. An interesting conclusion made from this project was that by elevating the pH of the influent, the DCPs undergo dissociation into ionic forms which are orders of magnitude more reactive to the oxidizers than the molecular forms.

Chemical Priming of Heavy PAH Contaminated Soils - (Sponsor Agency: US Navy Facilities Engineering Service Center and NOAA) - The objective of this effort is to prove the utility of using chemical oxidation as a biotreatment process enhancement technique for the improved removal of recalcitrant petroleum hydrocarbon (PAHs) from contaminated soils and sediments. The experimental approach is to evaluate peroxone, ozonation, and Fenton's Reagent for the partial breakdown of several heavy TPHs detected within soil/sediment matrices contaminated with petroleum hydrocarbons. It is postulated that partial oxidation will produce by-products that are more amenable to biodegradation due to reduced sorptive limitations and conversion of the parent TPH compounds to carboxylic and aldehyde aromatic groups. The targeted biotreatment process will be aerobic biocells, which is a technology that the PI developed while he was at the WES.

Development of Ozonation for Treatment of Wood Preserving Wastes Within Groundwater Matrices - (Sponsor: USEPA) - The objective of this effort was to develop and prove the utility of ozonation as an option for treating contaminated groundwaters. The focal point of this project was the design and construction of a pilot-scale ozonation unit and its evaluation at a wood preserving site in Mississippi. The TOC unit was extensively used to prove the degree of

mineralization obtained using the ozonation process. Results indicated that greater than 90% mineralization was obtained.

Development of *Insitu* Oxidation Processes - (Sponsor: DOD SERDP) - Working in collaboration with WES, MSU has recently been awarded a SERDP project to further assess limitations to the *insitu* oxidation of organic pollutants at DoD sites. Although, the approach to this project is somewhat applied, the equipment provided by ARO will be one of the key factors for tracking the fate of DoD pollutants during experimentation under this new project. It is strongly believed that the new capability provided MSU by ARO DURIP allowed MSU to be attractive to WES as a collaborator and also to be viewed by SERDP as having unique capability in this area. This capability is largely due to experience of the research staff at MSU and the new analytical capability provided to MSU by ARO.

PRINCIPAL INVESTIGATOR/EQUIPMENT CARETAKER

Dr. Mark E. Zappi, P.E. is a Professor of Chemical Engineering at Mississippi State University. Prior to accepting a position at MSU, Dr. Zappi worked as a research environmental engineer at the USAE Waterways Experiment Station (WES), Vicksburg, MS. The WES is the lead agency under the DoD for 6.2/6.3 development of remediation techniques for explosives remediation. While at the WES, Dr. Zappi was Head of the Biological and Oxidation Processes Research Team. His research activities included development of treatment technologies for various organic contaminants with particular emphasis placed on treatment of DoD wastes. Dr. Zappi was instrumental in the development and refinement of several innovative processes for explosives remediation which ranged in scope from small scale reactor experiments through to the performance of several on-site pilot studies. Other contaminants that were targeted by Dr. Zappi for treatment process development include petroleum hydrocarbons, chlorinated solvents, ketones, pesticides, phenolics, and chemical agents. Remediation technologies researched at WES under Dr. Zappi's leadership included UV/oxidation, photocatalysis, phytoremediation, bioslurry, biocells, and sonozone. During his tenure at the WES, Dr. Zappi interfaced with ARO Officials within a variety of capacities. Dr. Zappi received high ratings in 1995 during an ARO review of the 6.1 WES environmental remediation research efforts performed under the Department of the Army's Environmental Quality and Technology Program (EQT). Under EQT, Dr. Zappi was the Thrust Area Chairman for both Explosives Contaminated Soils and Groundwater Work Units. Dr. Zappi also served on the 1995 ARO Chemistry Coordinating and Planning Group held in Research Triangle

Park, NC. In 1996, Dr. Zappi received the WES Director's Research and Development Award, and in 1997, the Department of the Army's Research and Development Award for his research activities with the development of peroxone oxidation for treatment of explosives contaminated groundwaters. It is believed that Dr. Zappi's extensive research experience with DoD wastes provides him with a unique experience base for the continued support of the DoD environmental mission. Also, this DoD experience allows Dr. Zappi to have great familiarility with DoD needs and understanding of past research successes and failures which should eliminate or greatly reduce the potential for redundant research activities. Finally, Dr. Zappi has been very active within the USEPA's Superfund Program for implementing innovative treatment processes, allowing him to utilize this experience in support of the DoD for application of innovative techniques during future cleanup efforts. To date, since arriving at MSU, he has partnered with WES, AEC, Argonne National Laboratory, Oak Ridge National Laboratory, and The Navy Facilities Engineering Command in the drafting of several research plans which involve performance of research activities within the E-TECH Laboratory.

OTHER E-TECH RESEARCHERS

Several other researchers from the E-TECH Laboratory will obtain benefit from the capability the equipment provides. Outside of Dr. Zappi, the following key faculty members and their students benefitted directly from the acquisition of the system:

1. Dr. Chiang-Hai Kuo - Dr. Kuo's area of expertise is the evaluation of ozonation and advanced oxidation processes for treatment of contaminated aqueous and gaseous streams. He has obtained international exposure for his efforts in defining both kinetic and mechanistic processes during ozonation. Dr. Kuo has published over 30 peer-reviewed publications in this area and has served as major professor for over 15 graduates students (including Dr. Zappi). Dr. Kuo has revolutionized the use of stopped-flow spectrophotometry for evaluating rapid oxidation reactions. Over the years, he also has been instrumental in assisting the WES with evaluating future technology requirements.

2. Dr. Donald Hill - Dr. Hill is a professor of the Department of Chemical Engineering. Dr. Hill has provided consulting and research support to the WES in the areas of contaminant transport and treatment of heavy metal contaminated media. Dr. Hill is also Director of the Mississippi Technical Assistance Program (MISSTAP), which is a state-funded program which provides free technical assistance to Mississippi Industries for solving complex environmental problems. Dr. Hill has published his work in many of the most respected environmental engineering journals.

Currently, he is involved with the evaluation of an innovative biotreatment reactor for treating a complex industrial wastewater.

3. Dr. Cliff George - Dr. George is a highly respected expert on high temperature treatment processes which includes incineration, low thermal desorption, and microwave oxidation of organic contaminants. Dr. George spent over 12 years within the chemical processing industry prior to accepting a position at MSU. This "real-world" experience provides excellent teaching opportunities to chemical engineering students. Currently, Dr. George is evaluating several treatment techniques for contaminated off-gases from the paper and pulp industry. Dr. George has numerous publications in both environmental engineering and industry periodicals.

4. Dr. Mark Bricka - Dr. Bricka joined chemical engineering department at MSU in January of 2001. He currently serves as Co-Director of the MSU E-TECH Laboratory. He comes to MSU from the WES after years of leading research teams in the development of remediation processes for heavy metal contaminated matrices. Dr. Bricka continues to focus on heavy metals at MSU. In fact, he continues to collaborate with WES, AEC, and numerous DoD facilities on both the development of remediation processes and the elucidation of transport processes of metals within the environment. Dr. Bricka has recently purchased a Perkin-Elmer ICP system and a Perkin Elmer AA, which greatly enhances the capability of MSU toward supporting DoD related environmental research.

RATIONALE FOR DOD INVESTMENT IN MSU

The benfits to ARO support of this project have been divided into two categories: Technology Development Support and Education Opportunity Enhancement. Each category will be discussed below.

Technology Development Support - The equipment provides the MSU Department of Chemical Engineering's E-TECH Laboratory with a new horizon of research capabilities allowing the staff and students to better perform existing research efforts, while making MSU much more competitive and capable for continued performance of research in support of DoD's cleanup programs. The purchased system has allowed the staff and students within the E-TECH Laboratory to perform a variety of research functions that fall into the realm of either basic or applied research. Both of which are important within DoD's cleanup efforts. Examples of the capabilities that the new equipment brings to MSU are:

1. A dedicated environmental analytical tool for analysis of both known and unknown contaminants within environmental samples.
2. An analytical tool that will be used for determining by-products of incomplete contaminant degradation during development of treatment processes.

3. A complete system (GC/MS, TOC, sample oxidizer, and IC) that is very user friendly and durable which is important within a research facility that is providing an education opportunity to many students.

4. A complete system that has a high level of flexibility to support many differing projects within the environmental research area at one time.

Education Opportunity Enhancement - The contributions of the equipment to the educational mission of the MSU E-TECH Laboratory is multi-faceted. Several key aspects are listed and briefly discussed below:

1. Equipment Usage - The many graduate students working with the E-TECH Laboratory have controlled access to the purchased equipment. Their experience with state-of-the-art equipment and the potential of the requested equipment for greatly contributing to their research products is a critical component to their education as future environmental engineers. The purchased equipment has been used to support the education of four PhD candidates and seven MS students to date. Plus, over 10 undergraduate students have worked on the system purchased under the ARO DURIP projects over the past year. Clearly, the ARO investment has greatly enhanced the capability of MSU to educate future engineers. It is also interesting to note that over 50% of these students come from under-represented minority groups.

2. Collaborative Research With DoD Entities - The purchased equipment has allowed MSU researchers to be more appealing to DoD entities for performance of collaborative research efforts. This interaction provides MSU students with an educational experience that will provide opportunities in terms of technical exchange and learning how to perform research within a team structure. In fact, in March 2001, WES and MSU collaborated in the submittal of a joint SERDP proposal for the development of insitu chemical oxidation processes to address DoD problem pollutants. As mentioned earlier, this project has been funded. This interaction, from a MSU standpoint, is only possible via the newly acquired capability supplied with the purchased equipment.

3. Performance of Treatability Studies - One of the requirements of chemical engineering students working within the E-TECH Laboratory is that they participate in at least one applied research study (i.e. treatability study) outside of their formal graduate research. This provides the student with experience within the "real-world" of environmental engineering (which is an education within itself). The student becomes involved with meeting with industry representatives, regulators, and the design engineers. The purchased equipment, albeit not to date, will offer a new dimension of capability which should provide new opportunities and capability to support DoD treatability efforts. This informal education should provide engineers with both research and applications

experience for potential application within the DoD mission.

RESEARCH FACILITIES

Mississippi State University (MSU) is a comprehensive university with particular specialty in the areas of engineering and earth sciences making the university an excellent research environment for supporting many DoD related research missions. The Environmental Technology Research and Applications Laboratory (E-TECH Laboratory) of the Chemical Engineering Department is well-equipped with a wide variety of reactor systems and analytical equipment. Unique reactor systems available include ozonation chambers, ozone off-gas monitors, contact columns, biocells, lighted AOP reactors, and a high pressure, multi-component Parr reactor system. Analytical capability includes GC, HPLC, liquid scintillation counter, respirometer, MicroTox, IR analyzer, stopped-flow spectrophotometry, an ACE autoextaction unit, and VOA headspace analyzer.

APPENDIX A - MSU PURCHASE ORDER FOR EQUIPMENT

TELEPHONE
662/325-2550
FAX 662/325-8640

PAGE 1 OF 2

942-647-429-VP03

Mississippi State University

PURCHASE ORDER

Show this Purchase Order Number on all invoices and packages.

No. 990-25448

TO:
DIONEX CORPORATION
340 NORTH SAM HOUSTON PKWY.
SUITE 199
HOUSTON TX 77060

BILL TO:
MISSISSIPPI STATE UNIVERSITY
PROCUREMENT & CONTRACTS
POST OFFICE BOX 5307
MISSISSIPPI STATE MS 39762

SHIP TO:
MISSISSIPPI STATE UNIVERSITY
RECEIVING STATION
105 MILL STREET
STARKVILLE MS 39759

Please ship the following materials or items according to the terms, prices, and conditions given below:

TERMS	FOB	SHIP VIA
NET	SHIPPING POINT	BEST WAY

DATE OF ORDER	BID BY	MSU BID FILE	STATE CONTRACT
25-MAY-00	WILLIAM HAND 4063221-R1		MSU 00-322

QUANTITY		DESCRIPTION	UNIT PRICE	TOTAL PRICE
1	EA	055737 GS50 GRADIENT PUMP, STANDARD CONFIG.	11,500.0000	11,500.00
		LESS DISCOUNT		-6,834.00
1	EA	056963 ED50 ELECTROCHEMICAL DETECTOR, W/O CELLS	7,000.0000	7,000.00
1	EA	057302 GS50/IS25 SPARES KIT FOR PEEK STANDARD AND MICROBORE SYSTEMS	1,000.0000	1,000.00
1	EA	057001 LC30 CHROMATOGRAPHY OVEN, PEEK, REAR LOAD	7,000.0000	7,000.00
1	EA	044130 CONDUCTIVITY CELL, W/DS3	1,600.0000	1,600.00
1	EA	056830 AS40 AUTOMATED SAMPLER WITH STARTER VIAL KIT	5,300.0000	5,300.00
1	BX	046031 AS40 CASSETTES, 8 POSITION, 0.5ML	50.0000	50.00
1	EA	057171 PEAKNET 6 PN-2 WITH HARD PROTECT CARD	6,000.0000	6,000.00
1	EA	056417 DELL PENTIUM III WITH WINDOWS	2,300.0000	2,300.00
1	EA	055515 PRINTER	615.0000	615.00
1	EA	057005 DX-LAN PUMP INTERFACE CARD, 10BASET	700.0000	700.00
1	EA	057007 DX-LAN DETECTOR INTERFACE CARD 10BASET	800.0000	800.00
2	EA	044125 EO1 ELUENT ORGANIZER	300.0000	600.00
4	EA	044129 BOTTLE, 2 LITER, PLASTIC	140.0000	560.00
1	EA	044131 BO1 REGULATOR ACCESSORY	150.0000	150.00
1	EA	044187 BP2 COLUMN SWITCHING VALVE KIT, LC20/30	1,000.0000	1,000.00

POSTED

GM /LPB

CONTINUED

FUND	ORGANIZATION	ACCOUNT	PROGRAM	ACTIVITY	ORDER AMOUNT
301320	060300	408270	000000		41,236.00

I9006160
PAID
22428.32
7-11-00

PAID
7-11-00

I900
PAID
5989.70
7-12-00

RECEIVING SIGNATURE

AUTHORIZING SIGNATURE

PROCESSING SIGNATURE

REQUISITION NO. R0117030

DEPARTMENT: CHEMICAL ENGINEERING
129 ETHEREDGE-HARDY ROAD
MARK ZAPPI

RECEIVING REPORT VOUCHER

PAGE 2 OF 2

942-647-429-VP03

Mississippi State University

PURCHASE ORDER

on all invoices and packages

No. 990-25448

TO
DIONEX CORPORATION
340 NORTH SAM HOUSTON PKWY
SUITE 199
HOUSTON TX 77060

BILL TO
MISSISSIPPI STATE UNIVERSITY
PROCUREMENT & CONTRACTS
POST OFFICE BOX 5307
MISSISSIPPI STATE MS 39762

SHIP TO
MISSISSIPPI STATE UNIVERSITY
RECEIVING STATION
105 MILL STREET
STARKVILLE MS 39759

Please ship the following materials or items according to the terms, prices, and conditions given below:

TERMS	FOB	SHIP VIA
NET	SHIPPING POINT	BEST WAY

DATE OF ORDER	BID BY	MSU BID FILE	STATE CONTRACT
25-MAY-00	WILLIAM HAND 4063221-R1		MSU 00-322

QUANTITY		DESCRIPTION	UNIT PRICE	TOTAL PRICE
1	EA	051786 IONPAC AS9-HC 4-MM ANALYTICAL COLUMN	795.0000	795.00
1	EA	051791 IONPAC AG9-HC 4-MM GUARD COLUMN	250.0000	250.00
1	EA	053946 SUPPRESSOR, ASRS-ULTRA 4 MM	850.0000	850.00
		PURCHASE ORDER FAXED TO COMPANY ON MAY 25, 2000		
		(FOR CHEMICAL ENGINEERING)		

GM /LPB

FUND	ORGANIZATION	ACCOUNT	PROGRAM	ACTIVITY	ORDER AMOUNT
301320	060300	408270	021000		41,236.00

RECEIVING REPORT VOUCHER

RECEIVING SIGNATURE

AUTHORIZING SIGNATURE

PROCESSING SIGNATURE

VOUCHER NO.

REQUISITION NO. R0117309

FEDERAL

CHEMICAL ENGINEERING
129 ETHRIDGE-HARDY ROAD
MARK ZAPP

TELEPHONE
662/325-2550
AX 662/325-8640
PAGE 1 OF 1
521-035-956-VP03

Mississippi State University
PURCHASE ORDER

Show this Purchase Order Number on all invoices and packages.

No. 990-25758

TO
SHIMADZU
7102 RIVERWOOD DRIVE
COLUMBIA MD 21046

BILL TO
MISSISSIPPI STATE UNIVERSITY
PROCUREMENT & CONTRACTS
POST OFFICE BOX 5307
MISSISSIPPI STATE MS 39762

SHIP TO
MISSISSIPPI STATE UNIVERSITY
RECEIVING STATION
105 MILL STREET
STARKVILLE MS 39759

Please ship the following materials or items according to the terms, prices, and conditions given below:

NET	FOB: DESTINATION/PREPAY & ADD		SHIP VIA: BEST WAY
DATE OF ORDER: 31-MAY-00	BID BY: TED ASHBY TLA0025	MSU BID FILE:	STATE CONTRACT: MSU 00-321

QUANTITY	DESCRIPTION	UNIT PRICE	TOTAL PRICE
1 EA	220-95118-03 TOC-5000A REGULAR SENSITIVITY AUTO-AQUEOUS/SOLIDS SYSTEM TOTAL ORGANIC CARBON ANALYZER WITH START UP KIT AND RS-232 INTERFACE	38,600.0000	38,600.00
	LESS DISCOUNT		-7,021.50
1 EA	638-91044-02 POC ACCESSORY KIT	2,400.0000	2,400.00
1 EA	220-95237-04 PC UPGRADE KIT FOR TOC-5000/5050	340.0000	340.00
1 EA	638-41204-00 AIR PIPING SET	53.0000	53.00
	(FOR CHEMICAL ENGINEERING)		
			34,371.50

POSTED

GM /LPB

FUND	ORGANIZATION	ACCOUNT	PROGRAM	ACTIVITY	ORDER AMOUNT
301320	060300	408270	[illegible]		34,371.50

I0100134
PAID
34546.83
7-24-00

Ref #
MS91

RECEIVING SIGNATURE

AUTHORIZING SIGNATURE (Department Head or Administrator)

PROCESSING SIGNATURE

VOUCHER NO.

REQUISITION NO. R0117018 FEDERAL

CHEMICAL ENGINEERING
129 ETHEREDGE-HARDY ROAD
MARK ZAPPI

RECEIVING REQUISITIONER

TELEPHONE
662/325-2550
FAX 662/325-8640
PAGE 1 OF 1
431-350-[illegible]1-V[illegible]01

TO
UNITED LABORATORY PLASTICS
P.O. BOX [illegible]8585
ST. LOUIS MO 63126-0585

Mississippi State University

PURCHASE ORDER

Show this Purchase Order Number on all invoices and packages.

No. 001-08043

BILL TO
MISSISSIPPI STATE UNIVERSITY
PROCUREMENT & CONTRACTS
POST OFFICE BOX 5307
MISSISSIPPI STATE MS 39762

SHIP TO
MISSISSIPPI STATE UNIVERSITY
RECEIVING STATION
105 MILL STREET
STARKVILLE MS 39759

Please ship the following materials or items according to the terms, prices, and conditions given below:

TERMS	FOB	SHIP VIA
NET	DESTINATION/PREPAY & ADD	BEST WAY

DATE OF ORDER	BID BY:	MBU BID FILE:	STATE CONTRACT
15-SEP-00			

QUANTITY	DESCRIPTION	UNIT PRICE	TOTAL
1 EA	BC-14EF LAB FREEZER, TO -23C (FOR CHEMICAL ENGINEERING)	385.0000	[illegible]

Freezer S/N
WB026275[illegible]

AH /LPB

FUND	ORGANIZATION	ACCOUNT	PROGRAM	ACTIVITY	ORDER AMOUNT
01320	060300	408270	021000		385.00

POSTED

I0117995
PAID
500.00
10-26-00

RECEIVING SIGNATURE

AUTHORIZING SIGNATURE (Department Head or Administrator)

PROCESSING SIGNATURE

VOUCHER NO.

REQUISITION NO.
R0126434

FEDERAL

DEPARTMENT
CHEMICAL ENGINEERING
330 SWALM - PRESIDENT'S CIRCLE
MARK ZAPPI

RECEIVING REPORT VOUCHER

TELEPHONE
662/325-2550
FAX 662/325-8640
PAGE 1 OF 1
043-234-558-VP01

Mississippi State University

PURCHASE ORDER

Show this Purchase Order Number on all invoices and packages.

No. 990-27307

TO
WATERS CORPORATION
34 MAPLE STREET
MILFORD MA 01757-3696

BILL TO
MISSISSIPPI STATE UNIVERSITY
PROCUREMENT & CONTRACTS
POST OFFICE BOX 5307
MISSISSIPPI STATE MS 39762

SHIP TO
MISSISSIPPI STATE UNIVERSITY
RECEIVING STATION
105 MILL STREET
STARKVILLE MS 39759

Please ship the following materials or items according to the terms, prices, and conditions given below:

TERMS	FOB	SHIP VIA
NET 30	SHIPPING POINT	BEST WAY

DATE OF ORDER	BID BY	MSU BID FILE	STATE CONTRACT
22-JUN-00	DONNA BATES QUOTE NO. 20061402		MSU 00-338

QUANTITY		DESCRIPTION	UNIT PRICE	TOTAL
1	EA	176802000 GEL PERMEATION SYSTEM WITH THE FOLLOWING COMPONENTS: WAT207000 515 HPLC PUMP WAT078900 717 PLUS AUTOSAMPLER WAT081110 287 2-CHANNEL UV/VIS DETECTOR WAT042990 M32 ADD-ON SINGLE SYSTEM	26,136.0000	
1	EA	WAT047777 M32 INSTALLATION AND TRAINING	1,040.0000	
1	EA	WAT081158 2487 SEMI-PREP TAPER SLIT CELL	912.0000	
1	EA	725000142 DIVERTER VALVE, STANDARD	646.0000	
1	EA	WAT077342 2500 MICROLITER SYRINGE	120.0000	
1	EA	725000126 WATERS FRACTION COLLECTOR II	3,600.0000	
1	EA	WAT036554 ENVIROGEL GPC CLEANUP 19X300	2,048.0000	
1	EA	WAT036555 ENVIROGEL GPC CLEANUP 19X150	1,523.0000	
2	EA	WAT045275 TUBE 2.4ML LOOP ASSY	65.0000	
1	EA	186000492 XTERRA RP18 COLUMN 5UL 4.6X150MM	395.2500	
		PURCHASE ORDER FAXED TO COMPANY ON JUNE 22, 2000		
		(FOR CHEMICAL ENGINEERING)		
		POSTED		
JW /LPB				

FUND	ORGANIZATION	ACCOUNT	PROGRAM	ACTIVITY	ORDER AMOUNT
301320	060300	408270	021000		36,550.25

I9063176
PAID
36651.00
7-7-00

RECEIVING SIGNATURE

AUTHORIZING SIGNATURE (Department Head or Administrator)

PROCESSING SIGNATURE

VOUCHER NO.

REQUISITION NO. R0119440

FEDERAL

DEPARTMENT CHEMICAL ENGINEERING
129 ETHEREDGE-HARDY ROAD
MARK ZAPPI

RECEIVING REPORT VOUCHER

TELEPHONE
662/325-2550
FAX 662/325-8640

PAGE 1 OF 1

942-647-429-VP01

Mississippi State University

PURCHASE ORDER

Show this Purchase Order Number on all invoices and packages.

No. 001-13556

TO
DIONEX CORPORATION
ORDER PROCESSING DEPARTMENT
1228 TITAN WAY
SUNNYVALE CA 94088

BILL TO
MISSISSIPPI STATE UNIVERSITY
PROCUREMENT & CONTRACTS
POST OFFICE BOX 5307
MISSISSIPPI STATE MS 39762

SHIP TO
MISSISSIPPI STATE UNIVERSITY
RECEIVING STATION
105 MILL STREET
STARKVILLE MS 39759

Please ship the following materials or items according to the terms, prices, and conditions given below:

TERMS	FOB	SHIP VIA
NET 30	DESTINATION/PREPAY & ADD	BEST WAY

DATE OF ORDER	BID BY	MSU BID FILE	STATE CONTRACT
11-DEC-00	LARRY BELLAN 40631712R1		MSU 01-110

QUANTITY	DESCRIPTION	UNIT PRICE	TOTAL PRICE
1 EA	051995 ASE 200 SOLVENT CONTROLLER UPDATE KIT	4,324.0000	4,324.00
1 EA	053848 2L BOTTLES PACKAGE, SET OF THREE INCLUDES CAPS AND TUBE ASSEMBLY	750.0000	750.00
1 EA	047018 SERVICE AND INSTALL PEAKNET5 ALSO INCLUDES 960708 LINE CORD, 3COND, NORTH AMERICA AT NO CHARGE.	2,000.0000	2,000.00
	(FOR CHEMICAL ENGINEERING)		

POSTED

GM /LPB

FUND	ORGANIZATION	ACCOUNT	PROGRAM	ACTIVITY	ORDER AMOUNT
301320	060300	408270	021000		7,074.00

J013157
PAID
7140.00
1-26-01

RECEIVING REPORT/VOUCHER